Hurricane Protection and Storm Damage Reduction Model Development

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Shore Protection Model

- Unified Model
  - Can be used in many areas
  - Data-driven
- Engineering-Economic Model
- Coastal Engineering Processes as Driving Force
  - Storm Events
  - Beach Response
  - Nourishment Events
  - Recovery
- Incorporate Risk and Uncertainty
  - Life Cycle Monte Carlo Simulation Model

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Improvement over Existing Approaches

- Incorporate impact of multiple storm events
- Relax assumption that all storms impact same beach profile
- Better risk / uncertainty representation
- Assumptions made explicit
- Modern Framework (database, GIS links, visualization, etc.)

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Model Features

- Project Definition
  - project profile
  - beach nourishment schedules
- Nourishment strategies
  - beach placement environmental windows
  - advance nourishment / adaptive nourishment
  - budget-constrained nourishment
- Policies
  - rebuilding / armoring
- Handle non-structural solutions
  - polices that change structure inventory over time
    - removal
    - raising

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Model Components

- Coastal engineering processes
  - rely on existing tools
  - physical beach response to storm (SBEACH)
- Damages
  - Wave
  - Inundation
  - Erosion
  - Wind?
- Damage Functions
- Lot/Structure database

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Risk and Uncertainty Elements

- Damage Elements
  - structure value
  - land value
  - first floor elevation
- Damage Functions
  - 3 curves, describe range of expert estimates of damages
  - 25%, Most Likely, 75 % levels
- Storm
  - Timing with respect to tidal phasing
- Other
  - Shoreline retreat or eroded volume
  - Natural post-storm recovery

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Basic Concepts

- Event-Driven Model
  - Storm Events
  - Plausible Storms (Extended Historical)
- Simplified Beach Profile
  - Defined by Key points
  - Changed by storms, nourishment, recovery
- Pre-computed Beach Responses to Storms
  - Use SBEACH for range of profiles for each storm
- Damages
  - Damage Functions
  - Damage Elements

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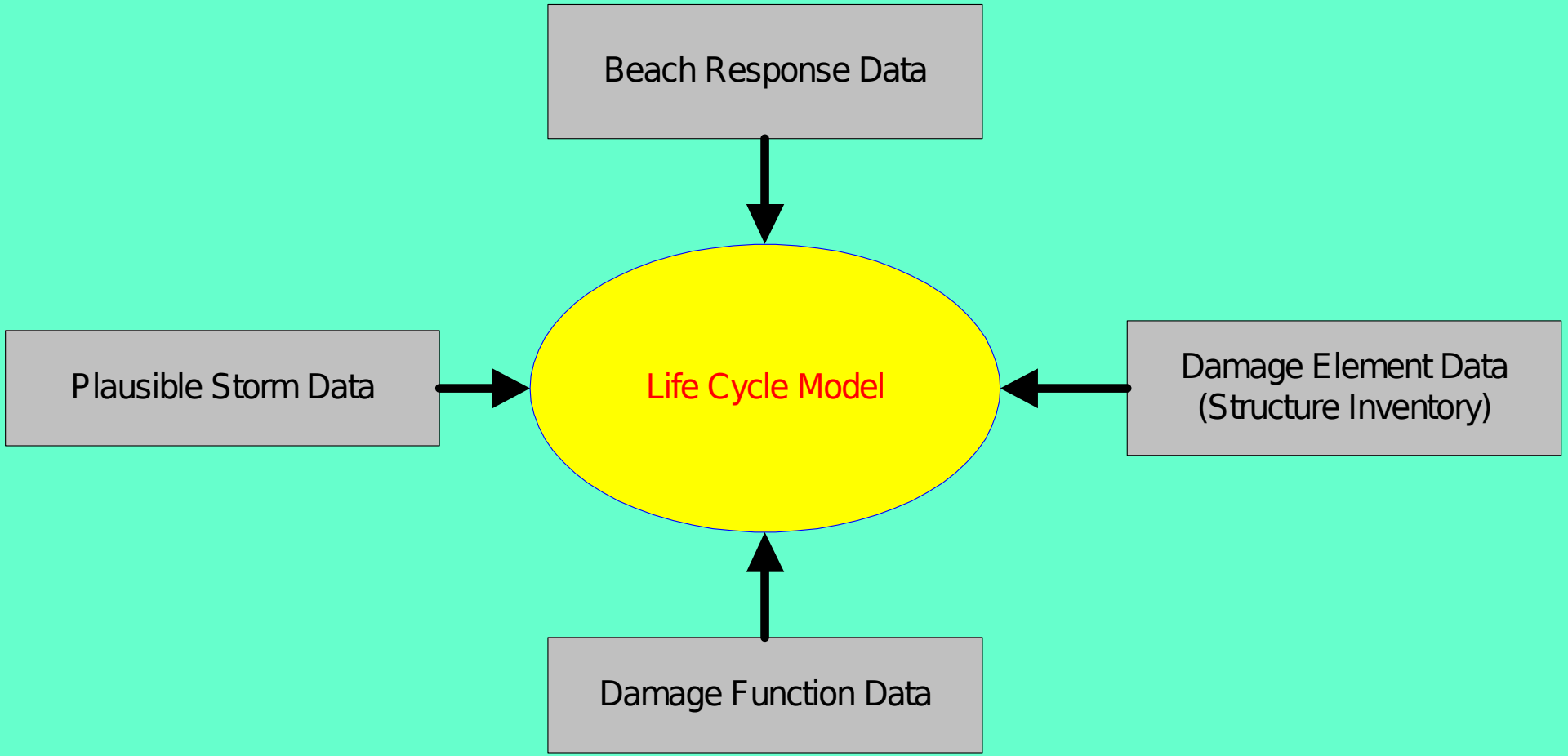
Data Driven Model



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Model Behavior for a Storm Event

- Storm Event (from database)
- Apply Beach Response for Storm to Current Beach Profile
- Develop Damage Parameters from Storm, Post-Storm Profile
- Calculate Damages from Damage Functions for each Damage element
- Recovery until Next Storm Event

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Storm Data

- Plausible storms based on historical data for site
- Combine Historical Time Series with 4 tidal positions
- Storm parameters (time series)
  - Storm waves
  - Water Levels
- Storm Date

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Beach Profile Representation

- Constants
  - Berm Height
  - Dune Slope
  - Upland Elevation
  - Foreshore Slope
  - Submerged Profile
- Variables (change with storm, management, recovery)
  - Berm Width
  - Dune Width
  - Dune Height

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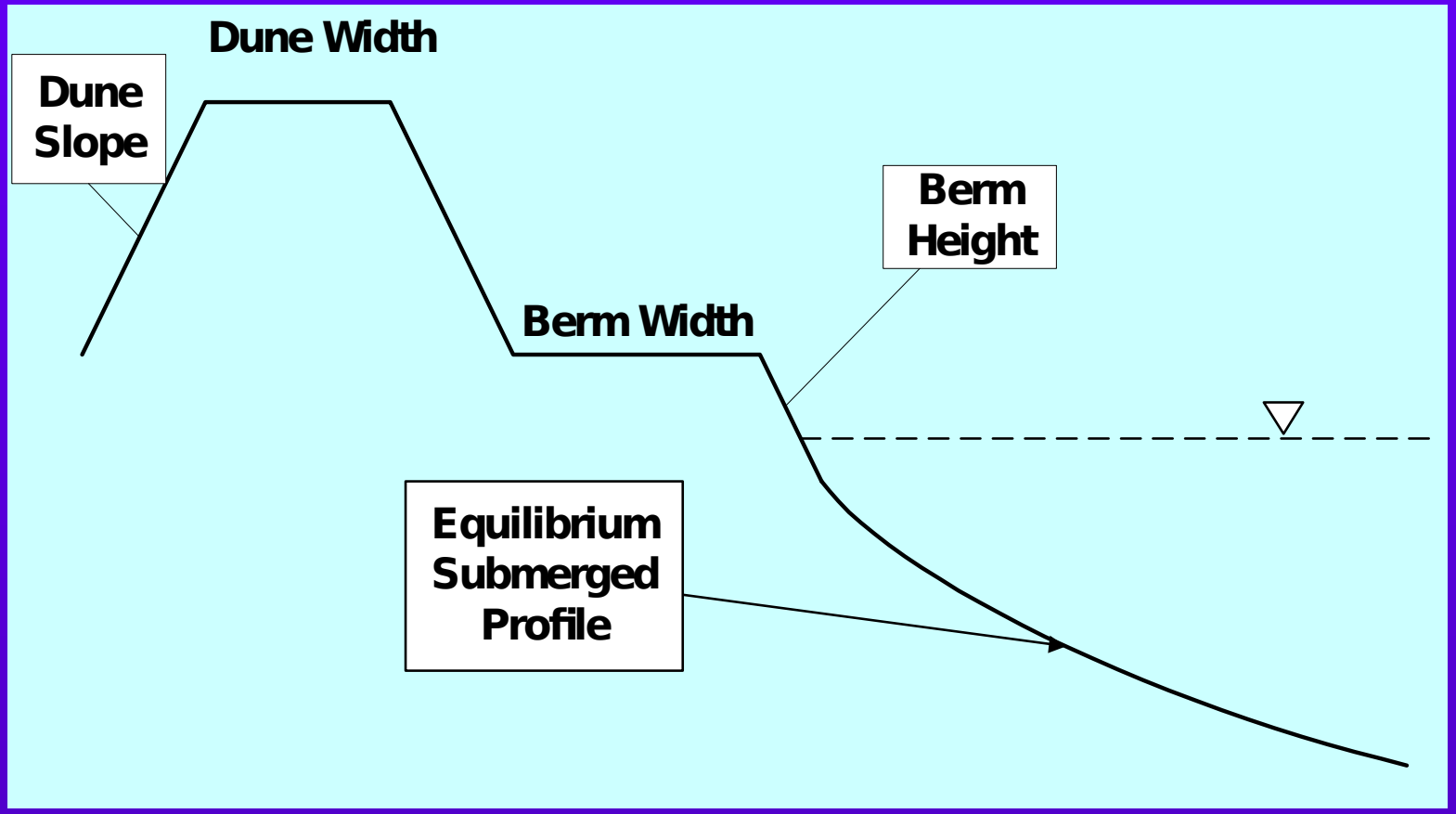
Beach Profile



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Beach Response Data

- Pre-computed set of SBEACH solutions for each storm
  - Input storm
  - Input profile
  - Output profile
- Store in Beach Response Database (BRD)

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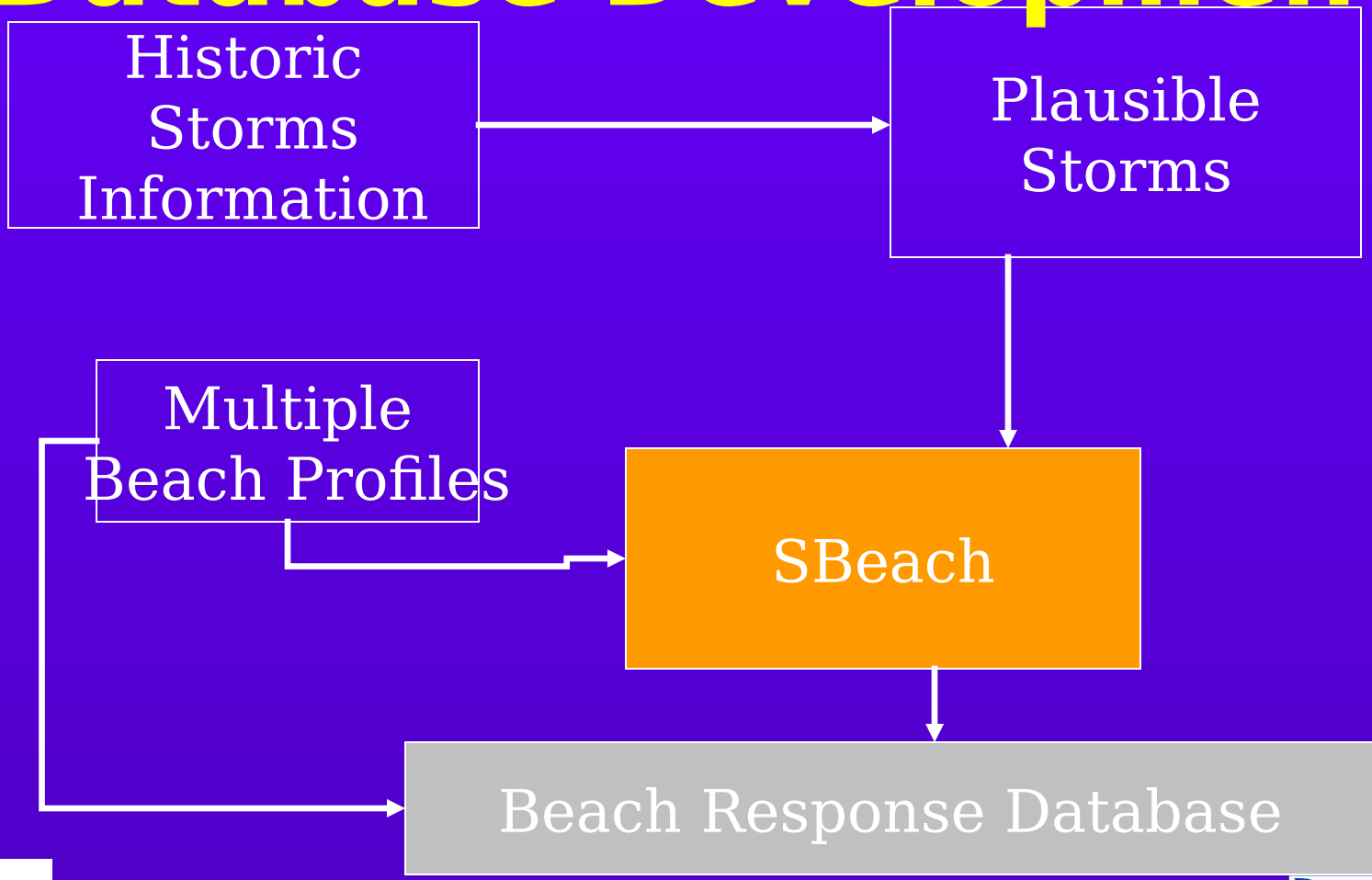
Beach Response Database Development



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Damage Elements

- Lot Information
- "Damage Elements" on lot
  - Location
  - Ground elevation
  - 1st floor elevation
  - structure type
  - structure value
  - contents value
  - type of armoring (if present)
  - rebuilding allowed?
  - time to rebuild

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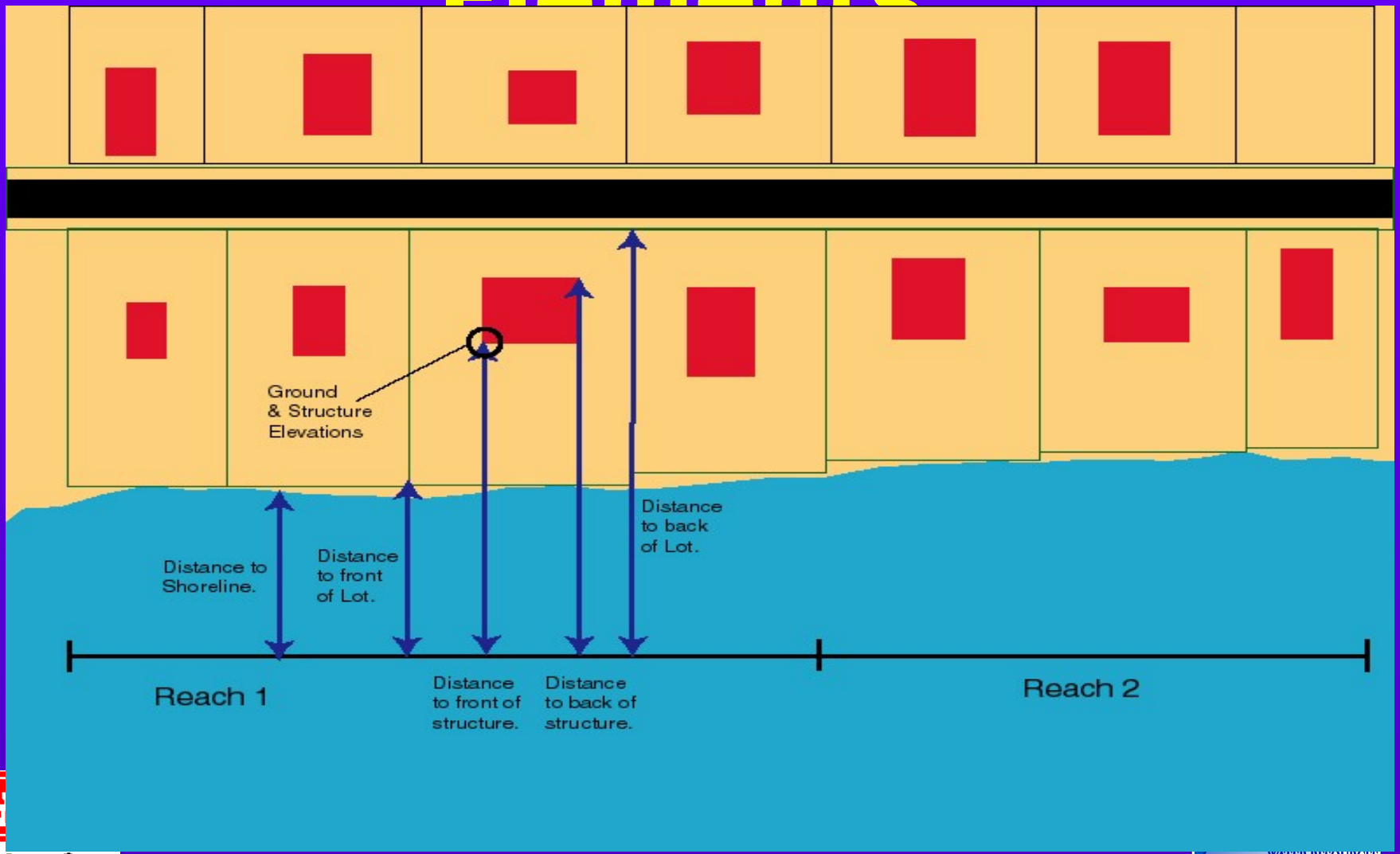
Lots / Damage Elements



Damage Functions

- For each:
  - damage element type (house, walkway, etc.)
  - Damage type (wave, flooding, etc.)
  - Foundation Type
- Define Curve of:
  - % Value Damaged = f(Driving Parameter)
- Driving Parameter is damage type-specific:
  - Flooding: Depth of water over lowest walking floor
  - Waves: (Wave crest) - (lowest horizontal member elevation)
  - Erosion: % of footprint compromised

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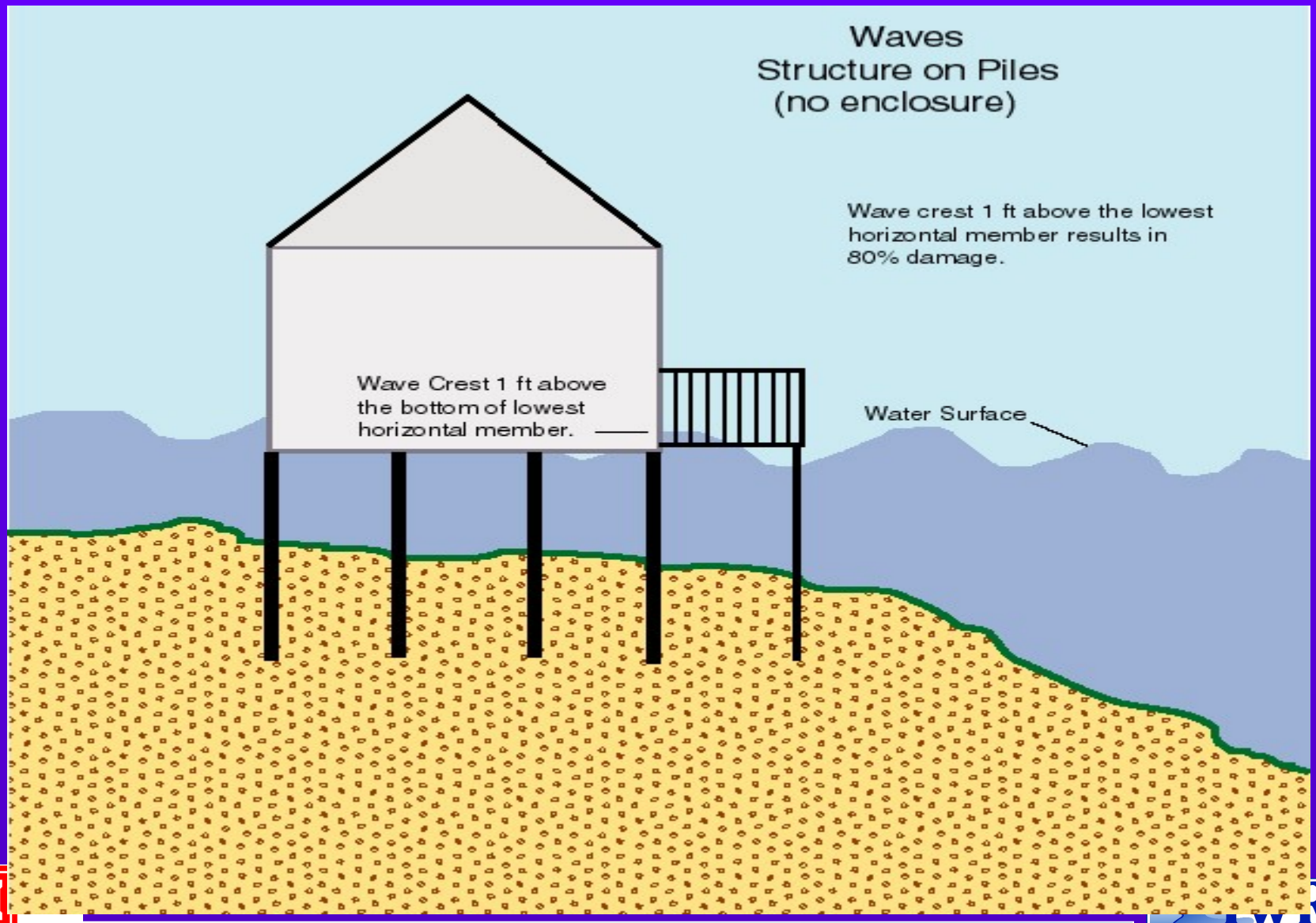
Waves
Structure on Piles
(no enclosure)
Wave crest 1 ft above the lowest horizontal member results in 80% damage.
Wave Crest 1 ft above the bottom of lowest horizontal member.
Water Surface

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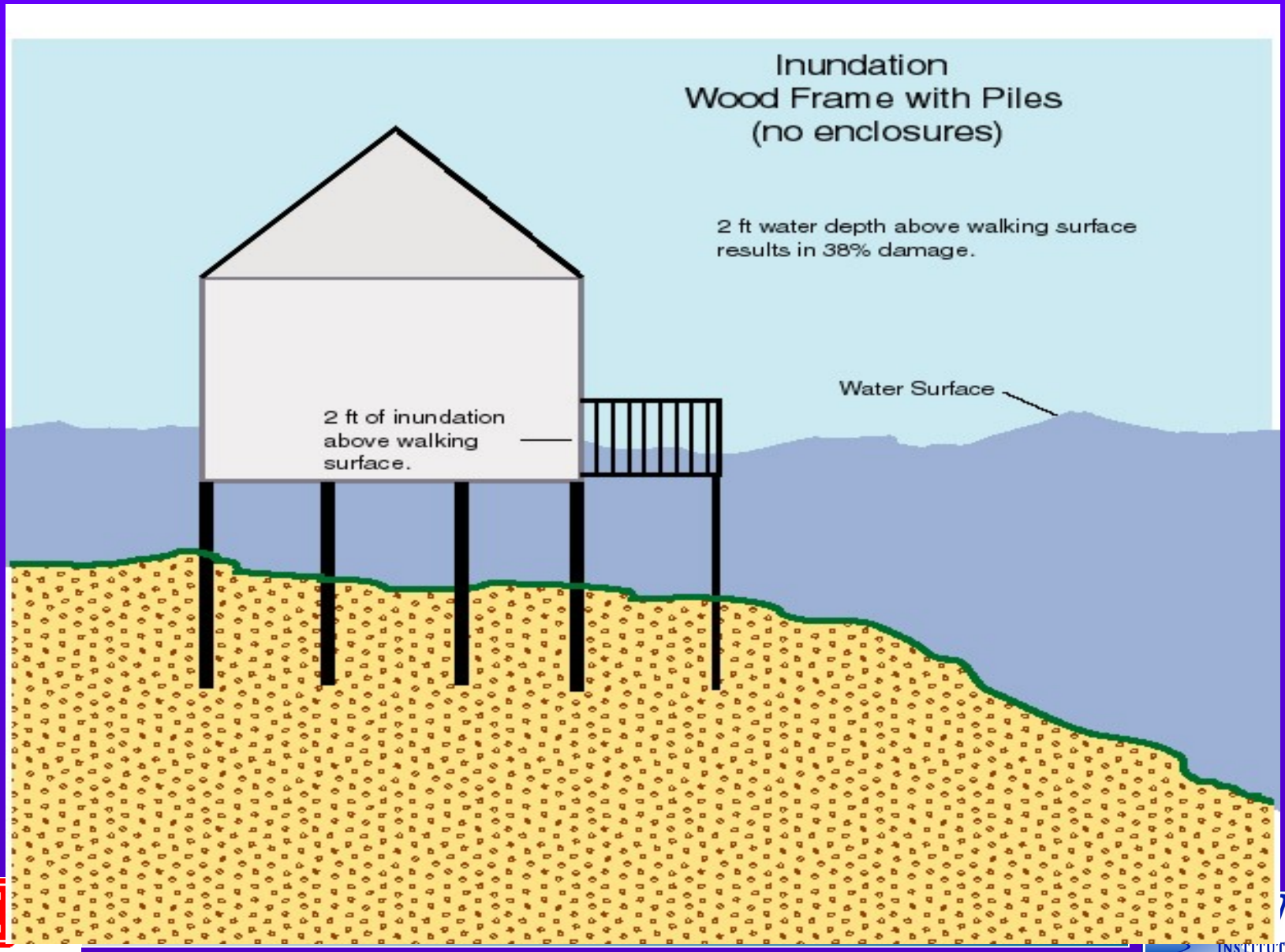

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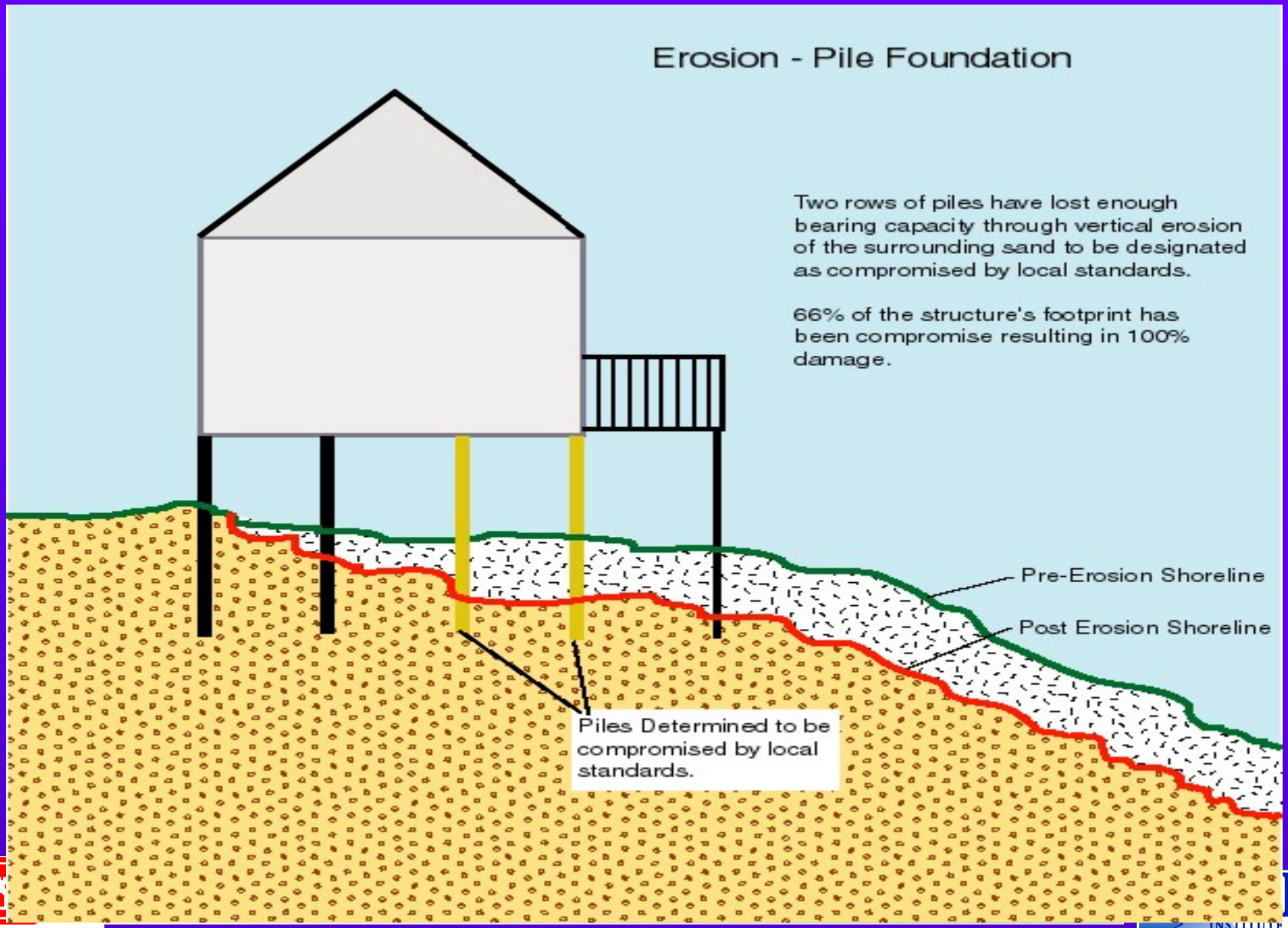
Erosion - Pile Foundation


Two rows of piles have lost enough bearing capacity through vertical erosion of the surrounding sand to be designated as compromised by local standards.
66% of the structure's footprint has been compromise resulting in 100% damage.
Pre-Erosion Shoreline
Post Erosion Shoreline
Piles Determined to be compromised by local standards.

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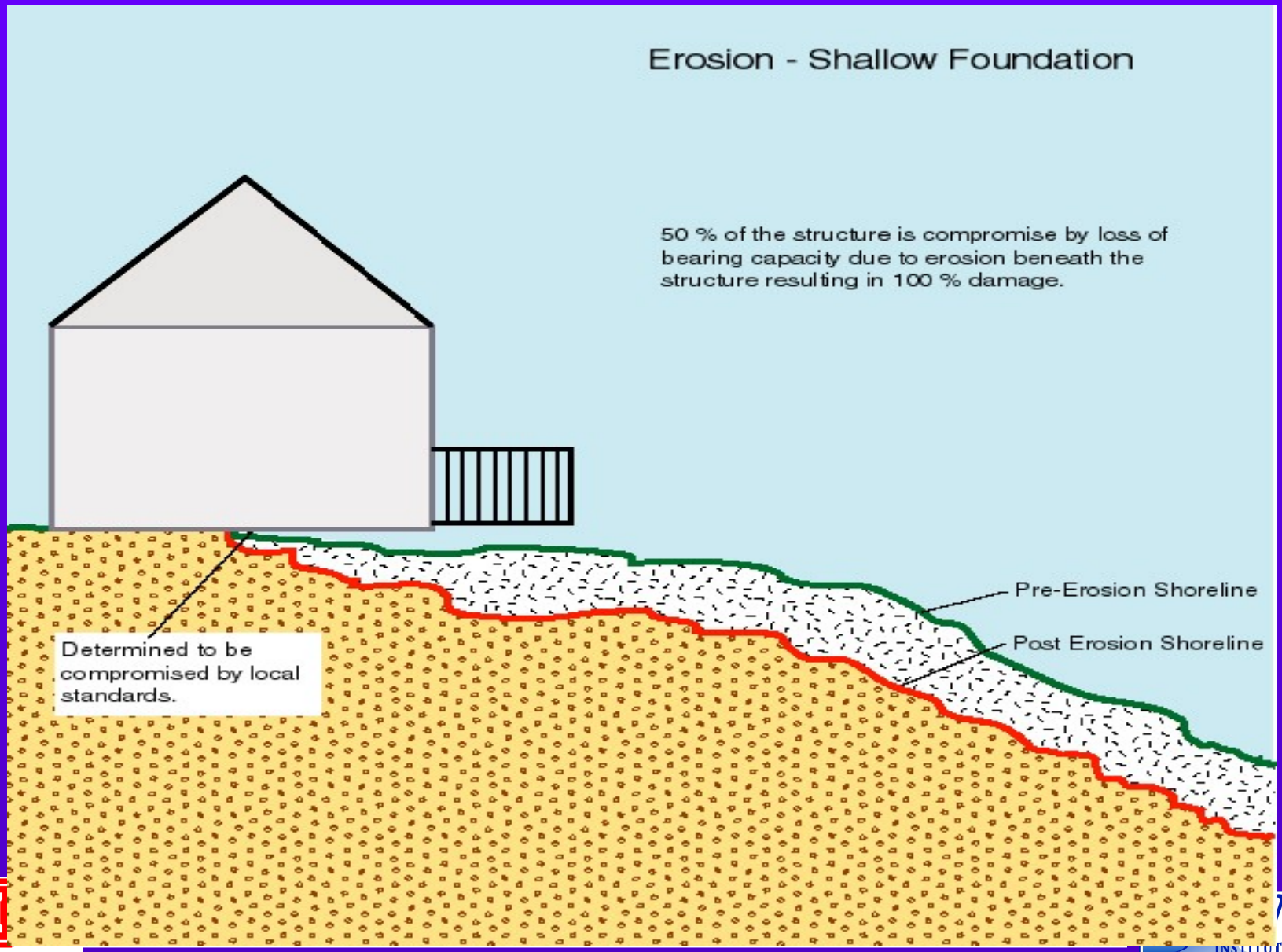
Erosion - Shallow Foundation
50 % of the structure is compromise by loss of bearing capacity due to erosion beneath the structure resulting in 100 % damage.
Pre-Erosion Shoreline
Post Erosion Shoreline
Determined to be compromised by local standards.

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Model Development Path

- Develop proof of concept model
  - performs the coastal engineering calculations
    - beach profile in response to a series of simulated storm
  - allow incorporation of beach nourishment
    - at specific times
    - adaptively (emergency)
- Add economic calculations
- Add user interface capabilities

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Model Status

- Design Documents
  - Overall Structure
  - Details of Model Components
- Proof of Concept Model and Database
  - Moves beach profile in response to storm events

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Proof of Concept Model

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Next Steps in Model Development

- Add with-project nourishment
- Refine Plausible Storm Generation Approach
- Implement Damage Analysis Design

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